MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

ETM 7156 – MOBILE WIRELESS COMMUNICATIONS

4 MARCH 2017
2:30 PM – 5:30 PM
(3 Hours)

INSTRUCTION TO STUDENT

1. This Question paper consists of 9 pages (including this cover page) with 5 Questions and 1 Appendix only.

2. Attempt **ALL FIVE** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the Answer Booklet provided. Please number your answers clearly.

Question 1

(a) Briefly explain the origin of the following types of interference in cellular communication systems and name the methods to mitigate them.

(i) Co-channel interference [2 marks]

(ii) Adjacent channel interference [2 marks]

(b) An urban city has a population of 500,000 residents. Three competing trunked mobile networks (systems A, B, and C) provide cellular service in this area. System A has 500 cells with 15 channels each, system B has 100 cells with 50 channels each, and system C has 50 cells, each with 90 channels. Each user averages 2 calls per hour at average call duration of 3 minutes. An Erlang B table is provided in the Appendix.

(i) What is the amount of traffic intensity contributed by a user (in the unit of Erlangs)? [2 marks]

(ii) Determine the number of users that can be supported by each system at 2% blocking, and the respective market penetration rate. [9 marks]

(iii) Compute the percentage market penetration rate of the three systems combined. [1 mark]

(c) Assume that you work as network engineer for a cellular service provider. In view of a significant growth in the number of subscribers, briefly describe how ***cell splitting*** and ***sectoring*** can be implemented to increase the system capacity in order to handle the increasing traffic.

[4 marks]

Continued ……

Question 2

(a) (i) Briefly describe the purpose of studying path loss models for mobile radio channels. [3 marks]

(ii) Describe in principle, how can one obtain the channel impulse response of a mobile radio channel. [2 marks]

(iii) Using a discrete-time 3D model, sketch an exemplary channel impulse response of a time-varying multipath radio channel versus time delay bins for different snapshots. [3 marks]

(b) The transmission tower of a small cell, *T*, serves a housing area by providing digital transmission to receiver units, *R*, installed in houses, where the average receiver antenna height is 9 m. Standing in between the transmission tower and the receivers is a small hill which peaks at 30 m. The hill can be modeled as a knife-edge obstruction as shown in Fig. Q2.1. The carrier frequency is 1800 MHz. Determine the knife-edge diffraction loss.

[*Hint*: The Fresnel-Kirchoff diffraction parameter is given as $v = \alpha\sqrt{\dfrac{2d_1 d_2}{\lambda(d_1 + d_2)}}$, where λ is the wavelength and the interpretations of other symbols are shown in Fig. Q2.1. You can make use of the following equations to find the diffraction loss.]

$$G_d(\text{dB}) = \begin{cases} 0, & v \le -1 \\ 20\log_{10}(0.5 - 0.62v), & -1 \le v \le 0 \\ 20\log_{10}(0.5\exp(-0.95v)), & 0 \le v \le 1 \\ 20\log_{10}\left(0.4 - \sqrt{0.1184 - (0.38 - 0.1v)^2}\right) & 1 \le v \le 2.4 \\ 20\log_{10}\left(\dfrac{0.225}{v}\right), & v > 2.4 \end{cases}$$

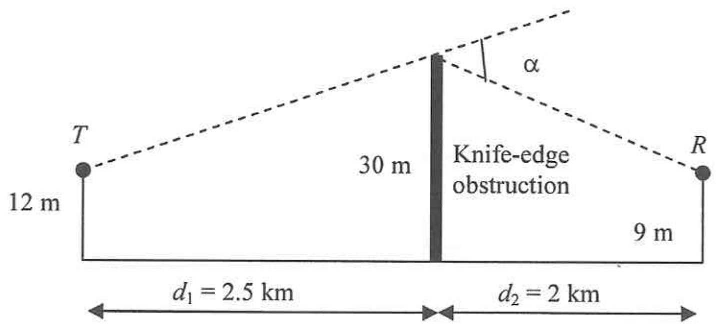

Fig. Q2.1

[8 marks]

Continued ......

(c) Fig Q2.2 depicts four cases of a mobile unit receiving radio signals from a cellular base station. Assuming the signals experience log-normal shadowing, sketch the received signal power versus distance for each case.

[4 marks]

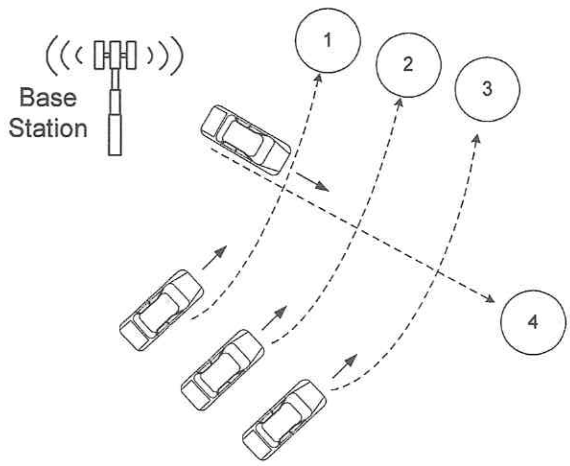

Fig. Q2.2

Continued ……

Question 3

(a) (i) What are the two important metrics that are commonly used to measure the bandwidth and power usage performance of a digital modulation scheme? Briefly describe each of them and state how they relate to each other generally.

[5 marks]

(ii) Why the error performance of digital modulation in slow flat-fading channels is poorer than that in additive white Gaussian noise channels? Suggest two countermeasures for performance improvement. [3 marks]

(b) A mobile radio system uses a modulation scheme with power spectral density (PSD) as shown in Fig. Q3, in which the horizontal axis shows the offset from the carrier frequency divided by the data rate. In any adjacent band the PSD must be at least 20-dB less than the maximum PSD of the wanted signal. However, due to the near-far effect (in which the interfering transmitter in an adjacent band is physically much closer to the receiver as compared to the intended transmitter), the adjacent band signal could become 30-dB greater. If the data rate is 10 kbps, use Fig. Q3 to estimate the maximum spacing between carriers (in Hz), and the bandwidth efficiency of the systems (in bit/s/Hz).

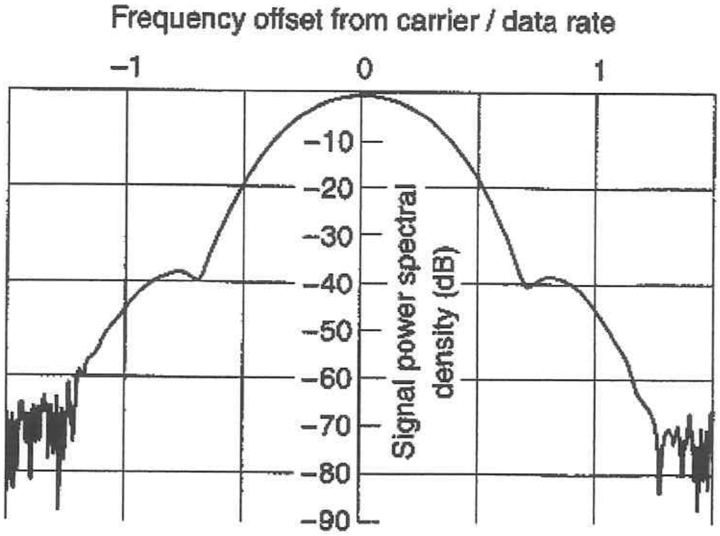

Fig. Q3

[5 marks]

(c) Adaptive modulation and coding (AMC) is a link adaptation technique commonly used in many modern cellular communication networks. What is the rationale of deploying AMC? Describe with the aid of a block diagram, the working principle of AMC and its key challenge in practical implementation.

[1+4+2 marks]

Continued ……

Question 4

(a) (i) What type of channels requires the use of non-linear channel equalizers? Why a linear channel equalizer will not suffice in such channels? [2 marks]

(ii) Assume that a channel introduces intersymbol interference so that the overall impulse response of a communication system is $h(t) = \delta(t) + 0.55\delta(t-T) + 0.43\delta(t-2T) + 0.25\delta(t-3T)$, where T is the symbol duration. If a zero-forcing equalizer is to be used, determine the resulting **equalized** impulse response of the communication system. [2 marks]

(iii) Sketch the block diagram of a maximum likelihood sequence estimator (MLSE) used to perform channel equalization for the Global System for Mobile (GSM) communications system. [4 marks]

(b) The probability that the signal-to-noise ratio (SNR) of a received signal is less than threshold γ of an M-independent branch diversity receiver is given by the following theoretical formula:

$$P_M(\gamma) = \left(1 - e^{-\gamma/\Gamma}\right)^M$$

where Γ is the mean SNR of each branch. We define outage as the situation when the received SNR is less than 15 dB.

(i) State the four major domains to implement diversity techniques. [2 marks]

(ii) Usually two antennas separated apart by a fraction of meter (> 1.5 times the wavelength) at the mobile stations are sufficient to exploit microscopic diversity. However, a separation distance of tens of wavelength is required if microscopic diversity is to be achieved at a base station. Explain the reason behind this phenomenon. [3 marks]

(iii) Determine the probability of outage when $M = 1$ and $\Gamma = 25$ dB. [2 marks]

(iv) Determine the value of M if a probability of outage of less than 0.5% for $\Gamma = 25$ dB is desired. [3 marks]

(v) Practical measurements carried out by an engineer show that the performance of an M-branch diversity receiver is poorer than that predicted by the theoretical formula given above. State a possible reason for the discrepancy. [2 marks]

Continued ......

Question 5

(a) Define the following terms:
  (i) Multiplexing [1 mark]
  (ii) Multiple-access [1 mark]
  (iii) Duplexing [1 mark]
  (iv) Carrier sensing [1 mark]

(b) Between Frequency Division Multiplexing (FDM) and Orthogonal Frequency Division Multiplexing (OFDM), which multiplexing scheme is more spectral efficient? Justify your answer with the aid of diagrams.
[5 marks]

(c) Fig Q5 shows the logical separation of a Time Division Multiple Access/Time Division Duplex (TDMA/TDD) transmission system.

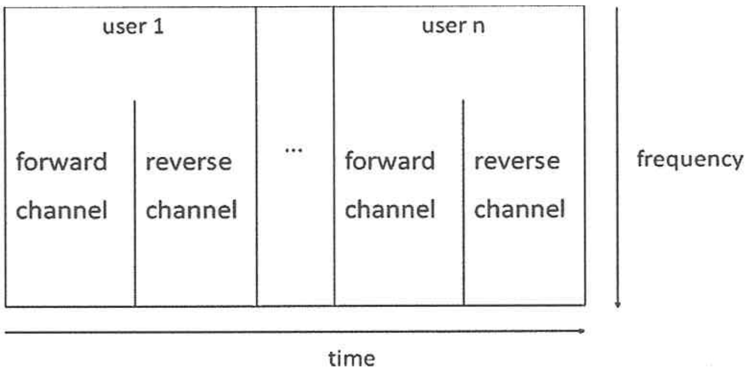

Fig. Q5

Using similar format, draw the logical separation diagram of the following transmission systems:
  (i) Frequency Division Multiple Access/Frequency Division Duplex (FDMA/FDD) [2 marks]
  (ii) FDMA/TDD [2 marks]
  (iii) TDMA/FDD [2 marks]

(d) Both a pure ALOHA and a slotted ALOHA networks individually transmit 400-bit frames on a shared channel of 400 kbps. The pure ALOHA network produces 200 frames per second, while the slotted ALOHA network produces 100 frames per second. Determine which network has higher throughput, percentagewise.
[5 marks]

End of Questions

Appendix: Erlang B Table

Erlang B Traffic Table

Maximum Offered Load Versus B and N

B is in %

N/B	0.01	0.05	0.1	0.5	1.0	2	5	10	15	20	30	40
1	.0001	.0005	.0010	.0050	.0101	.0204	.0526	.1111	.1765	.2500	.4286	.6667
2	.0142	.0321	.0458	.1054	.1526	.2235	.3813	.5954	.7962	1.000	1.449	2.000
3	.0868	.1517	.1938	.3490	.4555	.6022	.8994	1.271	1.603	1.930	2.633	3.480
4	.2347	.3624	.4393	.7012	.8694	1.092	1.525	2.045	2.501	2.945	3.891	5.021
5	.4520	.6486	.7621	1.132	1.361	1.657	2.219	2.881	3.454	4.010	5.189	6.596
6	.7282	.9957	1.146	1.622	1.909	2.276	2.960	3.758	4.445	5.109	6.514	8.191
7	1.054	1.392	1.579	2.158	2.501	2.935	3.738	4.666	5.461	6.230	7.856	9.800
8	1.422	1.830	2.051	2.730	3.128	3.627	4.543	5.597	6.498	7.369	9.213	11.42
9	1.826	2.302	2.558	3.333	3.783	4.345	5.370	6.546	7.551	8.522	10.58	13.05
10	2.260	2.803	3.092	3.961	4.461	5.084	6.216	7.511	8.616	9.685	11.95	14.68
11	2.722	3.329	3.651	4.610	5.160	5.842	7.076	8.487	9.691	10.86	13.33	16.31
12	3.207	3.878	4.231	5.279	5.876	6.615	7.950	9.474	10.78	12.04	14.72	17.95
13	3.713	4.447	4.831	5.964	6.607	7.402	8.835	10.47	11.87	13.22	16.11	19.60
14	4.239	5.032	5.446	6.663	7.352	8.200	9.730	11.47	12.97	14.41	17.50	21.24
15	4.781	5.634	6.077	7.376	8.108	9.010	10.63	12.48	14.07	15.61	18.90	22.89
16	5.339	6.250	6.722	8.100	8.875	9.828	11.54	13.50	15.18	16.81	20.30	24.54
17	5.911	6.878	7.378	8.834	9.652	10.66	12.46	14.52	16.29	18.01	21.70	26.19
18	6.496	7.519	8.046	9.578	10.44	11.49	13.39	15.55	17.41	19.22	23.10	27.84
19	7.093	8.170	8.724	10.33	11.23	12.33	14.32	16.58	18.53	20.42	24.51	29.50
20	7.701	8.831	9.412	11.09	12.03	13.18	15.25	17.61	19.65	21.64	25.92	31.15
21	8.319	9.501	10.11	11.86	12.84	14.04	16.19	18.65	20.77	22.85	27.33	32.81
22	8.946	10.18	10.81	12.64	13.65	14.90	17.13	19.69	21.90	24.06	28.74	34.46
23	9.583	10.87	11.52	13.42	14.47	15.76	18.08	20.74	23.03	25.28	30.15	36.12
24	10.23	11.56	12.24	14.20	15.30	16.63	19.03	21.78	24.16	26.50	31.56	37.78
25	10.88	12.26	12.97	15.00	16.13	17.51	19.99	22.83	25.30	27.72	32.97	39.44
26	11.54	12.97	13.70	15.80	16.96	18.38	20.94	23.89	26.43	28.94	34.39	41.10
27	12.21	13.69	14.44	16.60	17.80	19.27	21.90	24.94	27.57	30.16	35.80	42.76
28	12.88	14.41	15.18	17.41	18.64	20.15	22.87	26.00	28.71	31.39	37.21	44.41
29	13.56	15.13	15.93	18.22	19.49	21.04	23.83	27.05	29.85	32.61	38.63	46.07
30	14.25	15.86	16.68	19.03	20.34	21.93	24.80	28.11	31.00	33.84	40.05	47.74
31	14.94	16.60	17.44	19.85	21.19	22.83	25.77	29.17	32.14	35.07	41.46	49.40
32	15.63	17.34	18.21	20.68	22.05	23.73	26.75	30.24	33.28	36.30	42.88	51.06
33	16.34	18.09	18.97	21.51	22.91	24.63	27.72	31.30	34.43	37.52	44.30	52.72
34	17.04	18.84	19.74	22.34	23.77	25.53	28.70	32.37	35.58	38.75	45.72	54.38
35	17.75	19.59	20.52	23.17	24.64	26.44	29.68	33.43	36.72	39.99	47.14	56.04
36	18.47	20.35	21.30	24.01	25.51	27.34	30.66	34.50	37.87	41.22	48.56	57.70
37	19.19	21.11	22.08	24.85	26.38	28.25	31.64	35.57	39.02	42.45	49.98	59.37
38	19.91	21.87	22.86	25.69	27.25	29.17	32.62	36.64	40.17	43.68	51.40	61.03
39	20.64	22.64	23.65	26.53	28.13	30.08	33.61	37.72	41.32	44.91	52.82	62.69
40	21.37	23.41	24.44	27.38	29.01	31.00	34.60	38.79	42.48	46.15	54.24	64.35
41	22.11	24.19	25.24	28.23	29.89	31.92	35.58	39.86	43.63	47.38	55.66	66.02
42	22.85	24.97	26.04	29.09	30.77	32.84	36.57	40.94	44.78	48.62	57.08	67.68
43	23.59	25.75	26.84	29.94	31.66	33.76	37.57	42.01	45.94	49.85	58.50	69.34

(Continued on the next page)

Appendix 1: Erlang B Table (continued)

44	24.33	26.53	27.64	30.80	32.54	34.68	38.56	43.09	47.09	51.09	59.92	71.01
45	25.08	27.32	28.45	31.66	33.43	35.61	39.55	44.17	48.25	52.32	61.35	72.67
46	25.83	28.11	29.26	32.52	34.32	36.53	40.55	45.24	49.40	53.56	62.77	74.33
47	26.59	28.90	30.07	33.38	35.22	37.46	41.54	46.32	50.56	54.80	64.19	76.00
48	27.34	29.70	30.88	34.25	36.11	38.39	42.54	47.40	51.71	56.03	65.61	77.66
49	28.10	30.49	31.69	35.11	37.00	39.32	43.53	48.48	52.87	57.27	67.04	79.32
50	28.87	31.29	32.51	35.98	37.90	40.26	44.53	49.56	54.03	58.51	68.46	80.99
51	29.63	32.09	33.33	36.85	38.80	41.19	45.53	50.64	55.19	59.75	69.88	82.65
52	30.40	32.90	34.15	37.72	39.70	42.12	46.53	51.73	56.35	60.99	71.31	84.32
53	31.17	33.70	34.98	38.60	40.60	43.06	47.53	52.81	57.50	62.22	72.73	85.98
54	31.94	34.51	35.80	39.47	41.51	44.00	48.54	53.89	58.66	63.46	74.15	87.65
55	32.72	35.32	36.63	40.35	42.41	44.94	49.54	54.98	59.82	64.70	75.58	89.31
56	33.49	36.13	37.46	41.23	43.32	45.88	50.54	56.06	60.98	65.94	77.00	90.97
57	34.27	36.95	38.29	42.11	44.22	46.82	51.55	57.14	62.14	67.18	78.43	92.64
58	35.05	37.76	39.12	42.99	45.13	47.76	52.55	58.23	63.31	68.42	79.85	94.30
59	35.84	38.58	39.96	43.87	46.04	48.70	53.56	59.32	64.47	69.66	81.27	95.97
60	36.62	39.40	40.80	44.76	46.95	49.64	54.57	60.40	65.63	70.90	82.70	97.63
61	37.41	40.22	41.63	45.64	47.86	50.59	55.57	61.49	66.79	72.14	84.12	99.30
62	38.20	41.05	42.47	46.53	48.77	51.53	56.58	62.58	67.95	73.38	85.55	101.0
63	38.99	41.87	43.31	47.42	49.69	52.48	57.59	63.66	69.11	74.63	86.97	102.6
64	39.78	42.70	44.16	48.31	50.60	53.43	58.60	64.75	70.28	75.87	88.40	104.3
65	40.58	43.52	45.00	49.20	51.52	54.38	59.61	65.84	71.44	77.11	89.82	106.0
66	41.38	44.35	45.85	50.09	52.44	55.33	60.62	66.93	72.60	78.35	91.25	107.6
67	42.17	45.18	46.69	50.98	53.35	56.28	61.63	68.02	73.77	79.59	92.67	109.3
68	42.97	46.02	47.54	51.87	54.27	57.23	62.64	69.11	74.93	80.83	94.10	111.0
69	43.77	46.85	48.39	52.77	55.19	58.18	63.65	70.20	76.09	82.08	95.52	112.6
70	44.58	47.68	49.24	53.66	56.11	59.13	64.67	71.29	77.26	83.32	96.95	114.3
71	45.38	48.52	50.09	54.56	57.03	60.08	65.68	72.38	78.42	84.56	98.37	116.0
72	46.19	49.36	50.94	55.46	57.96	61.04	66.69	73.47	79.59	85.80	99.80	117.6
73	47.00	50.20	51.80	56.35	58.88	61.99	67.71	74.56	80.75	87.05	101.2	119.3
74	47.81	51.04	52.65	57.25	59.80	62.95	68.72	75.65	81.92	88.29	102.7	120.9
75	48.62	51.88	53.51	58.15	60.73	63.90	69.74	76.74	83.08	89.53	104.1	122.6
76	49.43	52.72	54.37	59.05	61.65	64.86	70.75	77.83	84.25	90.78	105.5	124.3
77	50.24	53.56	55.23	59.96	62.58	65.81	71.77	78.93	85.41	92.02	106.9	125.9
78	51.05	54.41	56.09	60.86	63.51	66.77	72.79	80.02	86.58	93.26	108.4	127.6
79	51.87	55.25	56.95	61.76	64.43	67.73	73.80	81.11	87.74	94.51	109.8	129.3
80	52.69	56.10	57.81	62.67	65.36	68.69	74.82	82.20	88.91	95.75	111.2	130.9
81	53.51	56.95	58.67	63.57	66.29	69.65	75.84	83.30	90.08	96.99	112.6	132.6
82	54.33	57.80	59.54	64.48	67.22	70.61	76.86	84.39	91.24	98.24	114.1	134.3
83	55.15	58.65	60.40	65.39	68.15	71.57	77.87	85.48	92.41	99.48	115.5	135.9
84	55.97	59.50	61.27	66.29	69.08	72.53	78.89	86.58	93.58	100.7	116.9	137.6
85	56.79	60.35	62.14	67.20	70.02	73.49	79.91	87.67	94.74	102.0	118.3	139.3
86	57.62	61.21	63.00	68.11	70.95	74.45	80.93	88.77	95.91	103.2	119.8	140.9
87	58.44	62.06	63.87	69.02	71.88	75.42	81.95	89.86	97.08	104.5	121.2	142.6
88	59.27	62.92	64.74	69.93	72.82	76.38	82.97	90.96	98.25	105.7	122.6	144.3
89	60.10	63.77	65.61	70.84	73.75	77.34	83.99	92.05	99.41	107.0	124.0	145.9
90	60.92	64.63	66.48	71.76	74.68	78.31	85.01	93.15	100.6	108.2	125.5	147.6

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